Improving Mobile IPv6 Handover in Wireless Network with E-HCF

Anne Wei, Gouzhi Wei, Benoit Geller

Improving Mobile IPv6 Handover in Wireless Network with E-HCF

Anne Wei*†, GouZhi Wei*and Benoit Geller‡§
*Université Paris XII, 61 avenue du Général de Gaulle, 94030 Créteil, France
† Conservatoire National des Arts et Métiers, 292, rue Saint-Martin, 75003,Paris,France
‡SATIE – ENS Cachan, 61 avenue du Président Wilson, 94235 Cachan Cedex,France
§LEI – ENSTA, 32 boulevard Victor, 75015 Paris Cedex,France
Email: anne.wei@cnam.fr

***Abstract*— Mobile IP allows a mobile node to maintain a continuous connectivity to the Internet when moving from one access point to another. However, due to the link switching delay and to the Mobile IP handover operations, packets designated to mobile nodes can be delayed or lost during the handover period. This paper presents a new control function called Extended Handover Control Function (*E-HCF*) in order to improve the handover performance in the context of Mobile IPv6 over wireless networks. With an analytical model and some OPNET simulations, we show in this paper that our solution allows to provide low latency, low packet loss to the standard handover of Mobile IPv6.**

***Index Terms*— Mobile IPv6, Performance and Handover operations**

I. Introduction

THE need to keep an "everywhere and at any time" connection with Internet has been more and more demanded in recent years with the success of IEEE 802.11 and of IEEE 802.16 wireless networks standards. A growing number of 802.16/802.11 based wireless networks has been deployed in campuses, hotels, airports and companies as access networks to the Internet. The mobility support has thus become one very hot research subject. However, the continuous Internet connectivity and the correct routing of packets were not guaranteed when users change their access points to Internet with classical protocols. To resolve these problems, the Mobile IPv4 (*MIPv4*) and Mobile IPv6 (*MIPv6*)protocols [1], [2] were respectively published by the Internet Engineering Task Force (*IETF*).

Based on *MIPv6*, the main standards by the *IETF* are the Hierarchical Mobile IPv6 (*HMIPv6*) and the Fast Handover for MIPv6 (*FHMIPv6*). *HMIPv6* introduces a Mobility Anchor Point (*MAP*) who acts somehow like a local Home Agent *(HA)* for the visiting Mobile Node *(MN)*. The concept of *MAP* can limit the amount of signaling required outside the *MAP*'s domain [5], [7]. *FHMIPv6* [8] can reduce the packet loss by providing fast IP connectivity as soon as a new link at the Link Layer is established. The network uses a Link Layer trigger to launch either Pre-Registration or Post-Registration handover operations. Besides of these main proposals, there has been some approaches for providing the lossless handover and minimizing the handover delay [9]–[12], [14]. In [9], a Pre-Handover Signaling (*PHS*) protocol is proposed in order to support the triggering of a predictive handover and to allow the network to achieve accurate handover decisions by considering different constraints such as Quality-of-Service (*QoS*), user profile and mobile node service requirements. In [10], a Hierarchical Network-layer Mobility Management (*HNMM*) framework is described in which an integrated IP-layer handover solution provides an optimized network connectivity. Also, a Competition based Soft Handover Management (*CSHM*) protocol [11] and a Multi-path Transmission Algorithm (*MTA*) [12] have been presented to decrease packet loss during a handover. Furthermore, the IEEE 802.11f standard including the Inter-Access Point Protocol (*IAPP*) enables the Access Points *(APs)* to communicate with each other, so that the Mobile IPv6 handover is improved at the Link Layer [14].

The goal of this paper is to optimize the Mobile IPv6 handover procedure by using a new function named Extended Handover Control Function (*E-HCF*). Based on our paper [3], the principle of the Handover Control Function (*HCF*) is that, according to the mobile node's scanning result and the HCF router database, the *HCF* router can both pre-decide a mobile node's new access point and a new IP address. So the mobile node can send Binding Update message when it is still connected with its previous access point. Contrarily to a standard MIPv6 handover for which the Detection Address Duplication (*DAD*) deteriorates dramatically the handover latency (see below), the *HCF* approach avoids any IP address collision without the use of DAD. In this context, we propose the *E-HCF* which not only inherits of the advantages of the *HCF*, but also allows communications between some extra-*HCF* routers. Moreover, the *E-HCF* can buffer the packets during the handover process in order to reduce the packet loss. The remainder of the paper is thus organized as follows: Section II presents our Extended Handover Control Function (*E-HCF*) architecture and the associated operations. Section III deals with the performance of the *E-HCF* handover in terms of handover latency and packet loss. Regarding the standard handover of *MIPv6*, Our numerical and simulation results show that the *E-HCF* handover reduces significantly both the latency and the packet loss. Finally, some conclusion and future works are mentioned in Section IV.

This work was supported in part by the international project PRA-SIP under Grant SIP04-03.

II. EXTENDED HANDOVER CONTROL FUNCTION FOR MOBILE IPV6

A. E-HCF overview

Generally speaking, a handover consists of a Link Layer handover and of a Network Layer handover. The Link Layer handover includes a Discovery phase (scanning the channels to discover an available Access Point), an Authentication phase, and a Re-association phase, whereas the Network Layer handover is concerned by a Router Discovery phase, a Detection Address Duplication (*DAD*) phase, a Binding Update phase and a Binding Acknowledgement phase respectively. As displayed on Figure 1, the standard MIPv6 handover latency has been estimated to a maximum value of 1290 ms [7]. This long latency is not acceptable for real time applications such as video and audio. If we analyze each phase during the Network Layer handover (Router Discovery, *DAD*, Binding Update and Binding Acknowledgement), we can note that the *DAD* latency costs almost 1000 ms and has a heavy weight on the global handover latency. As a result, in order to reduce the total handover latency, we now develop a procedure to avoid any *DAD* operation during handover procedure.

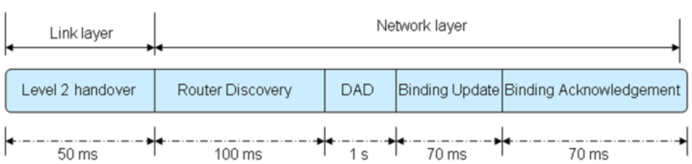

Fig. 1. Standard MIPv6 Latency

We introduce a local intelligent entity called Extended Handover Control Function (*E-HCF*) which should be capable of controlling its attached Access Routers (*ARs*), Access Points (*APs*) and Mobile Nodes (*MNs*). As shown on Figure 2, linked directly with its ARs, each *E-HCF* router reserves beforehand a list of all available IP local addresses. The *E-HCF* router also generates and updates periodically a second list which records the used ARs/APs/IP addresses. By comparing these two lists, the *E-HCF* router can find a potential duplicate IP address (collision) in its domain. Then, this *E-HCF* router can withdraw this potential duplicate IP address or can ask a concerned sub-node to change its IP address. In this way, the *E-HCF* router enables to insure an unique IP address to a *MN* without DAD.

Furthermore, an *E-HCF* router could exchange both some local information with its ARs/APs/MNs and some external information with other *E-HCF* routers. To realize our *E-HCF* proposal, we propose six new messages: MN Request (*MNReq*), MN Reply (*MNRep*), HCF Request (*HCFReq*), HCF Reply (*HCFRep*), Connection Established Information (CEInf) and Handover Finished Confirmation (*HFCon*) messages (for the detailed information about the formats of these messages see [15]).

For the mobile IPv6 protocol and IEEE 802.11/802.16 networks context, a *MN* surveys periodically the received signal strength. When the signal strength drops below a pre-defined threshold, the *MN* must discover and connect itself to a new available *AP* for granting its communication with its

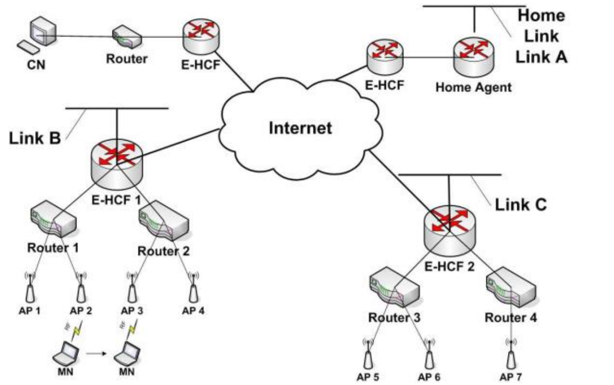

Fig. 2. Architecture of Extended Handover Control Function (Router is an Access Router; E-HCF is an E-HCF router)

correspondence. It reports to its *E-HCF* router (via its attached *AR/AP*) some *AP*'s Basic Service Set IDentifier (*BSSID*) and signal strengths that it were probed. Based upon the reported information, the *AR/AP*'s loading and the *MN*'s Quality of Service (*QoS*) requirements, the *E-HCF* router decides which *AP*, the *MN* shall associate with and notifies the *MN* about the new *AR/AP* information, such as a new *AP*'s *BSSID*, an *AR* interface address, a sub-network prefix and an IP address. Consequently, the *MN* can configure its new Care-of-Address (*CoA*) and can take care of the Binding Update process even if it is still attached with its previous *AR/AP*. An *E-HCF* router can guarantee that the new IP address is unique thanks to the knowledge of its lists. If a *MN* moves to another domain, the *E-HCF* original router guarantees the new IP address by exchanging some data with the new *E-HCF* router. Moreover, in order to minimize the packet loss during a handover, an *E-HCF* router stores packets into a buffer until the *MN* is really attached to the new IP address. The entire handover procedure is displayed on Figure 3.

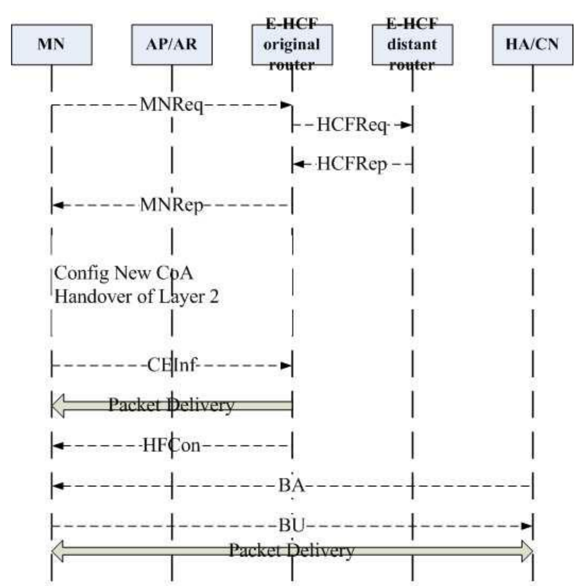

Fig. 3. E-HCF Procedure (E-HCF original router is an attached router with an E-HCF function; the E-HCF distant/remove router is a router with who an E-HCF original router can communicate)

B. E-HCF Procedure

We first recall that *HCFReq/HCFRep* messages are used between *E-HCF* routers for extra-domain handovers. Each *E-HCF* router must record and update its database periodically. This database helps to decide an unique new IP configuration in order to adapt for *MN* movements without the *DAD* phase during a handover.

As illustrated on Figure 3, the *E-HCF* procedure is composed of the following steps:

- Moving in the network, if the threshold of the received signal strength is overstepped, the *MN* begins to probe the neighbor *AR/A*P's information, including the signal strength, some IP addresses, *AP*'s *BSSIDs*, *AR* interface addresses and the sub-network prefix. Then the *MN* sends a *MNReq* message to its *E-HCF* original router (via its *AR/AP*) to report this information.
- Receiving the *MNReq* message, the *AR* stops to forward all the packets sent to the *MN* and forwards them to its *E-HCF* original router in order to avoid the packet loss during the handover procedure.
- Receiving the *MNReq* message, the *E-HCF* original router decides to which *AR/AP* the *MN* will be associated. The choice of the *AR/AP* is mostly based on database obtained with periodic exchange messages from an *E-HCF* router to another (*HCFReq* and *HCFRep* messages) or with periodic exchange messages from *ARs/APs/MNs*. For example, if the number of registered *MN*s in one *AR* or *AP* has reached a limit, the *E-HCF* original router will not attach the *MN* to this saturated *AR* or *AP*. After making the previous decision, the *E-HCF* original router sends to the *MN* a *MNRep* message which consists of a new *AP*'s *BSSID*, an *AR* interface address, a sub-network prefix and a new IP address.
- With the *MNRep* message, the *MN* can obtain its new *CoA* and configure it automatically.
- The *MN* sends a *CEInf* message to its *E-HCF* original router to confirm its new attachment.
- After receiving the *CEInf* message, the *E-HCF* original router transfers the buffered packets to the *MN*'s new *CoA*. Then, the *E-HCF* original router sends an *HFCon* message to end the handover procedure.
- The *MN* can then exchange Binding Update (*BU*) and Binding Acknowledgement (*BA*) messages with its home agent and its correspondent node.

As shown in the *E-HCF* procedure, a *MN* can obtain its new *CoA* before it really attaches to its next *AR/AP*. Moreover, any *DAD* latency (about 1000 ms) is avoided. Thus, the *E-HCF* approach allows the reduction of both the traditional handover latency and the packet loss. The handover performance is thus optimized compared to a traditional approach.

III. E-HCF Performance Estimation

The *E-HCF* performance estimation has been evaluated in terms of the total handover latency and of the packet loss with an analytical model. This model allows us to compare our *E-HCF* handover with the standard handover of the MIPv6 protocol.

A. E-HCF Latency Analysis

According to the handover procedure on Figure 3, we cite the following latency notations to estimate the handover latency:

- L_{EHCF}: Total handover latency with the *E-HCF* approach.
- L_{scan}: Latency due to the *MN*'s original scanning of its neighbour *AR/AP*'s information.
- L_{MNReq}: Latency for a *MN* to send a *MNReq* message to its *E-HCF* original router.
- L_{dec}: Latency necessary to an *E-HCF* router to decide which *AR/AP* the *MN* should be attached (including the short delays to send an *HCFReq* message and to receive an *HCFRep* message).
- L_{MNRep}: Latency for an *E-HCF* router to send a *MNRep* message to the *MN*.
- L_{CNinf}: Latency necessary for a *MN* to auto-configure its new *CoA*.
- L_{conf}: Latency due to the fact that an *E-HCF* router sends buffered packets and a *HFCon* message.
- $L_{BU/BA}$: Binding Update/Binding Acknowledgement latency.

The overall *E-HCF* handover latency L_{EHCF} can be summed as following:

$$\begin{aligned} L_{EHCF} = \\ & L_{scan} + L_{MNReq} + L_{dec} + L_{MNRep} + \\ & L_{CNinf} + L_{conf} + L_{BU/BA} \end{aligned} \tag{1}$$

As this L_{EHCF} depends upon the mobile link bandwidth and the computation capacity of each entity in the wireless network, we summarize the parameter values used in our numerical analysis in Table I.

TABLE I
PARAMETER SETTING

Parameter	Value	Comment
Channel scan time	50 ms	MIPv6 standard
BU/BA latency	140 ms	MIPv6 standard
Wireless link bandwidth	5.5 Mb/s	IEEE 802.11b
Wireless link bandwidth	2 Mb/s	UMTS
Wireless link bandwidth	150 kb/s	GPRS
Wireless link bandwidth	9 kb/s	GSM
AR computation capacity	20 Mb/s	general router
MN computation capacity	10 Mb/s	PC computation capacity
MNReq message size	72 byte	E-HCF approach
MNRep message size	45 byte	E-HCF approach
HCFReq message size	45 byte	E-HCF approach
HCFReq message size	45 byte	E-HCF approach
CEInf message size	45 byte	E-HCF approach
HFCon message size	24 byte	E-HCF approach

B. Numerical Results of the Total E-HCF Latency

With the parameters of Table I, we give a latency comparison between the standard handover latency and the *E-HCF* latency according to equation (1). These latencies are functions of the wireless link bandwidths (WiFi, UMTS, GPRS and GSM) and of the computation capacity. For example, the

L_{MNReq} latency can be numerically estimated as following: with a 10 Mb/s computation capacity, a *MN* needs 57.6 μs to generate a 72-byte *MNReq* message, whereas, 28.8 μs are required for an Access Router. Putting this 72-byte message on a 9kb/s GSM network, requires about 64 ms, so that the global of L_{MNReq} is about 64 ms.

On Figure 4, the standard MIPv6 handover latency (1290 ms) is the first figure displayed on the left. The rest of the figures are the *E-HCF* handover latencies based on WiFi, UMTS, GPRS and GSM link bandwidths. We note that the various *E-HCF* latencies are not really different when link bit rates vary from 150 kb/s to 5.5 Mb/s. If the link bit rate drops to 9 kb/s (GSM), the *E-HCF* handover latency raises up to 450 ms. As a result, the wireless link bandwidth has an important influence over the overall handover procedure. Let us focus on the *E-HCF* latency with the IEEE 802.11b wireless networks. The average of the *E-HCF* handover latency is about 200 ms. This value of 200 ms is validated by our simulation results on OPNET illustrated on Figure 5.

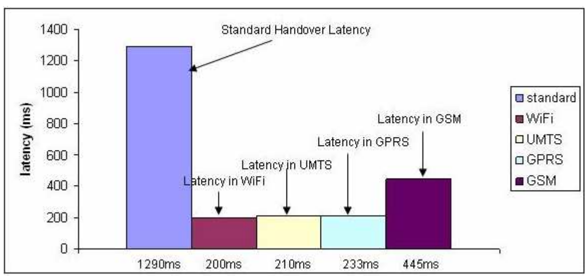

Fig. 4. E-HCF handover latencies as a function of wireless link bandwidths

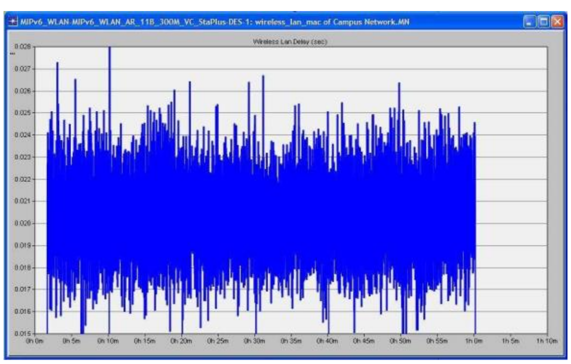

Fig. 5. E-HCF handover latency by simulation

Although the latency reduction from 1290 ms to 200 ms is significant, the value of 200 ms is still too long to support a real time application in wireless networks. This is due to the number of channel scans. As a results, we propose a fast *E-HCF* method in which a *MN* can immediately request its *E-HCF* router without probing for the connection information, if the threshold of the received signal strength is overstepped. The *E-HCF* router then decides the next attached point. Our simulation results show that the average of the fast E-HCF latency can drop to 100 ms.

C. E-HCF Loss

In terms of packet loss with the *E-HCF* approach, packets can be stored into a buffer during the handover (see subsection II-B). Figure 6 illustrates the comparison of packet loss rates between the E-HCF approach and the MIPv6 standard. The upper curve represents the number of lost packets with the MIPv6 standard (38 packets received out of 100 emitted packets), whereas the bottom curve with E-HCF approach (68 packets received out of 100 emitted packets). This gives a typical 30% gain with the E-HCF approach.

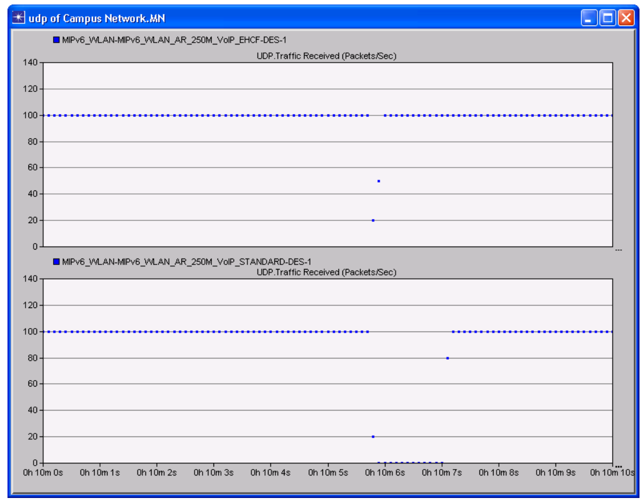

Fig. 6. Comparison of loss rates between the E-HCF approach and the MIPv6 standard by simulation

IV. Conclusion

In order to improve the handover performance for the Mobile IPv6, this paper studies an original *E-HCF* approach which allows to collect and store some link and network data. Regarding the classical Mobile IPv6 handover performance, our numerical results validated by simulations show that the *E-HCF* approach enables to decrease both the total handover latency and the packet loss significantly.

We focused on the handover performance at the Network Layer. We now are interested to also improve the handover performance at the Link Layer with a ”graph” solution. Our future goal aims at improving the handover performance both at the Network Layer for the Mobile IPv6 and at the Link Layer for IEEE 802.11 networks with a cross-layer proposal.

References

[1] C. Perkins, ”IP Mobility support for IPv4,” RFC 3220, IETF, January 2002.
[2] D. Johnson, C. Perkins, and J.Arkko, ”Mobility Support in IPv6,” RFC 3775, June 2004.
[3] G. Z. Wei, A. Wei, K. Xu and H. Deng, ”Handover Control Function Based Handover for Mobile IPv6,” In Proceedings of Workshop of Evolution towards Next Generation Internet (ICCS 2006), University of Reading, UK, 28-31 May 2006.
[4] C. E. Perkins, Tutorial Mobile Networking through Mobile IPv4, Sun Microsystems, `http://www.computer.org/internet/v2n1/perkins.html`. 2005
[5] H. Soliman, C. Castelluccia, K. Malki, and L. Bellier, ”Hierarchical Mobile IPv6 mobility management (HMIPv6),” RFC 4140, August 2005.

[6] H. Fathi, S.H. Shin, K. Kobara, and al, ”Leakage-Resilient security Architecture for Mobile IPv6 in Wireless overlay Networks,” IEEE Journal on Selected Areas in Communications, vol. 23, No. 11, pp.2182-2193, November 2005.
[7] Wei Kuang Lai and Jung Chia Chiu, ”Improving Handoff Performance in Wireless Overlay Networks by Switching between Two-Layer IPv6 and One-Layer IPv6 Addressing,” IEEE Journal on Selected Areas in Communications, vol. 23, No. 11, pp. 2129-2137, November 2005.
[8] R. Koodli, Ed. ”Fast Handovers for Mobile IPv6,” RFC 4068, July 2005.
[9] H. Chaouchi and P. Antunes, ”Pre-handover Signaling for QoS Aware Mobility Management,” International Journal of Network Management, No. 14, pp.367-374, 2004.
[10] Y. Bi, P. Iyer, ”An Integrated IP-layer Handover Solution for Next Generation IP-based Wireless Network”, IEEE Vehicular Technology Conference VTC2004-Fall, Vol. 6, pp.3950-3954, Los Angeles, USA, 2004
[11] J. Kristiansson and P. Parnes, ”Application-layer Mobility Support for Streaming Real-time Media,” Wireless Communications and Networking Conference, Vol.1, pp.268-273, Atlanta, USA, 2004.
[12] S. Kashihara, K. Iida and al, ”End-to-End Seamless Handover Using Multi-path Transmission Algorithm,” International Conference on Internet Computing 2002, IC’02, pp. 1-7, Las Vegas, USA, 2002.
[13] ”IPv6 Address Allocation and Assignment Policy,” doc no. ripe-267, `http://www.ripe.net/ripe/docs/ipv6policy.html`,January 2003
[14] ”IEEE 802.11f: Recommended Practice for Multi-Vendor Access Point Interoperability via an Inter-Access Point Protocol Access Distribution Systems Supporting IEEE 802.11 Operation”, IEEE Standard 802.11, January 2003
[15] Guozhi Wei, ”Handover Optimisation using E-HCF Method for the Mobile IPv6 protocol,” thesis, University of Paris XII, France, February, 2008.
[16] J. Bournelle and M. Laurent-Marknavicius, ”Adaptation et implementation de Diameter/AAA pour Mobile IPv6, ” `http://www-rp.lip6.fr/dnac/5.1-bournelle-article.pdf`, 2004
[17] A. Patel, K. Leung et al, ”Authentication Protocol for Mobile IPv6,” RFC 4285, January, 2006.
[18] J. Arkko, V. Devarappli and F. Dupont, ”Using IPSec to Protect Mobile IPv6 Signaling Between Mobile Nodes and Home Agents,” RFC 3776, June 2004.